Presentation to the
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UAVSAR

AIRBORNE L-BAND RADAR FOR REPEAT PASS INTERFEROMETRY

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Outline

Science Need

Aircraft Overview

Historical Background

Science Applications

Future Capabilities

Questions

Science Need

Natural and Human forces are constantly changing the Earth system …
both the interior and atmosphere ….

… sometimes causing violent or long-term changes to terrestrial ecosystems in which life depends

Gulfstream-III (C-20A) UAVSAR

G-III Specifications

Crew:	Two Pilots
Length:	83 feet, 2 inches
Wingspan:	77 feet, 10 inches
Engine:	Two Rolls-Royce Spey 511-8 turbofan engines
Altitude:	45,000 ft (max)
Range:	3,400 nm
Duration:	5 hrs (nominal); 7 hrs (max) (.82M @ 37kft)
Cruise Mach:	0.85 (max)
Aircraft Sytems	Satellite communications, satellite phone, 120-amp electrical power system, centerline pylon with standard MAU-12 mount capable of carrying 1200 lb externally, internal cabin rack mounting

G-III/UAVSAR Historical Background

- G-III / UAVSAR Program began in 2004 funded by NASA
- Partnership between NASA Dryden (manages the G-III aircraft) and NASA JPL (manages the UAVSAR)
- The primary objectives of the UAVSAR Project were to:
  – develop a miniaturized polarimetric L-band synthetic aperture radar (SAR) for use on an unmanned aerial vehicle (UAV) or piloted vehicle
  – develop flight technique and associated processing algorithms for repeat-pass differential interferometric measurements using a single antenna
  – conduct measurements of geophysical interest, particularly changes of rapidly deforming surfaces such as volcanoes or earthquakes (however, applications have grown beyond surface deformation)
- Two complete L-band systems were developed
- A precision autopilot allows repeat trajectories within a 5 m radius tube.
- Operational Science Missions began on February 18, 2009 … concurrent development and testing of the radar system continues

Key Radar Instrument Parameters

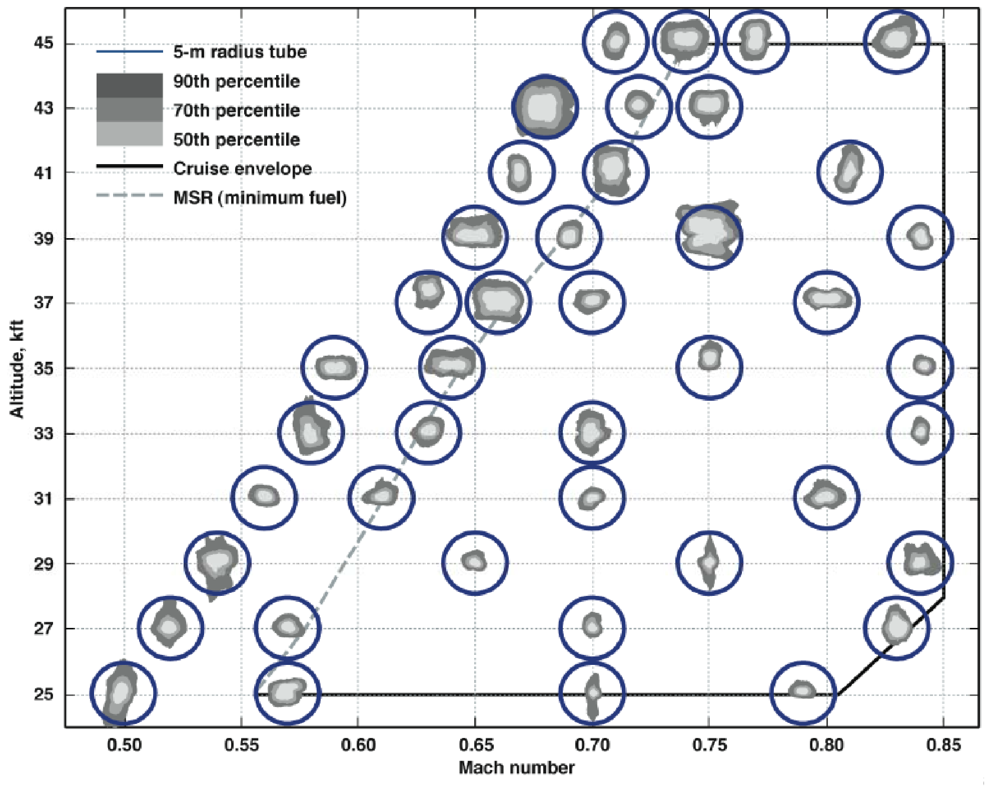
Parameter	Value
Frequency	L-Band 1217.5 to 1297.5 MHz
Bandwidth	80 MHz
Resolution	1.67 m Range, 0.8 m Azimuth
Polarization	Full Quad-Polarization
ADC Bits	2,4,6,8,10 & 12 bit selectable BFPQ, 180Mhz
Waveform	Nominal Chirp/Arbitrary Waveform
Antenna Aperture	0.5 m range/1.5 azimuth (electrical)
Azimuth Steering	Greater than ±20° (±45° goal)
Transmit Power	> 3.1 kW
Polarization Isolation	<-25 dB (<-30 dB goal)

Repeat-pass Capability

To support science applications requiring repeat pass observations, the UAVSAR design incorporates:

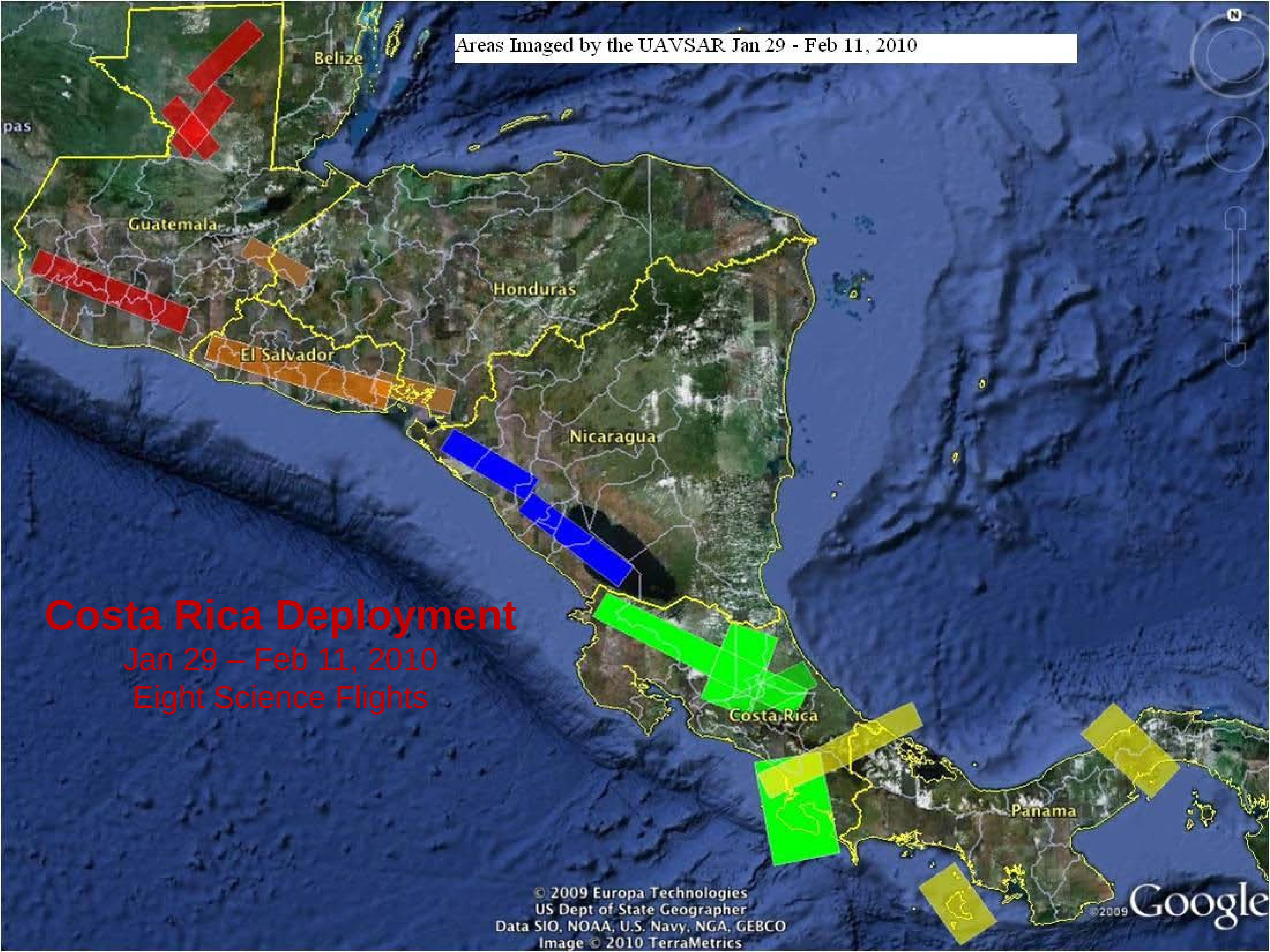
- A precision autopilot developed by NASA Dryden that allows the platform to fly repeat trajectories that are mostly within a 5 m radius tube.
- Compensation for attitude angle changes during and between repeat tracks by electronically pointing the antenna based on attitude angle changes measured by the INU.

Results from Validation Test Flights Using 220km lines at each flight condition



UAVSAR Applications

- Earth Surface Deformation
  - ✓ Volcanoes
  - ✓ Fault Lines / Earthquakes
  - ✓ Ice Dynamics
  - ✓ Levee Evaluation
  - ✓ Surface Subsidence
  - ✓ Landslide Prediction
  - ✓ Coastline Subsidence
- Terrestrial Ecology
- Soil Moisture (50 mm into ground)
- Oil Spill
- Archeology



Areas Imaged by the UAVSAR Jan 29 - Feb 11, 2010
Belize
pas
Guatemala
Honduras
El Salvador
Nicaragua
Costa Rica
Panama
Costa Rica Deployment
Jan 29 – Feb 11, 2010
Eight Science Flights
© 2009 Europa Technologies
US Dept of State Geographer
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2010 TerraMetrics
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"Ring of Fire" Volcanoes

Aleutian Islands, AK

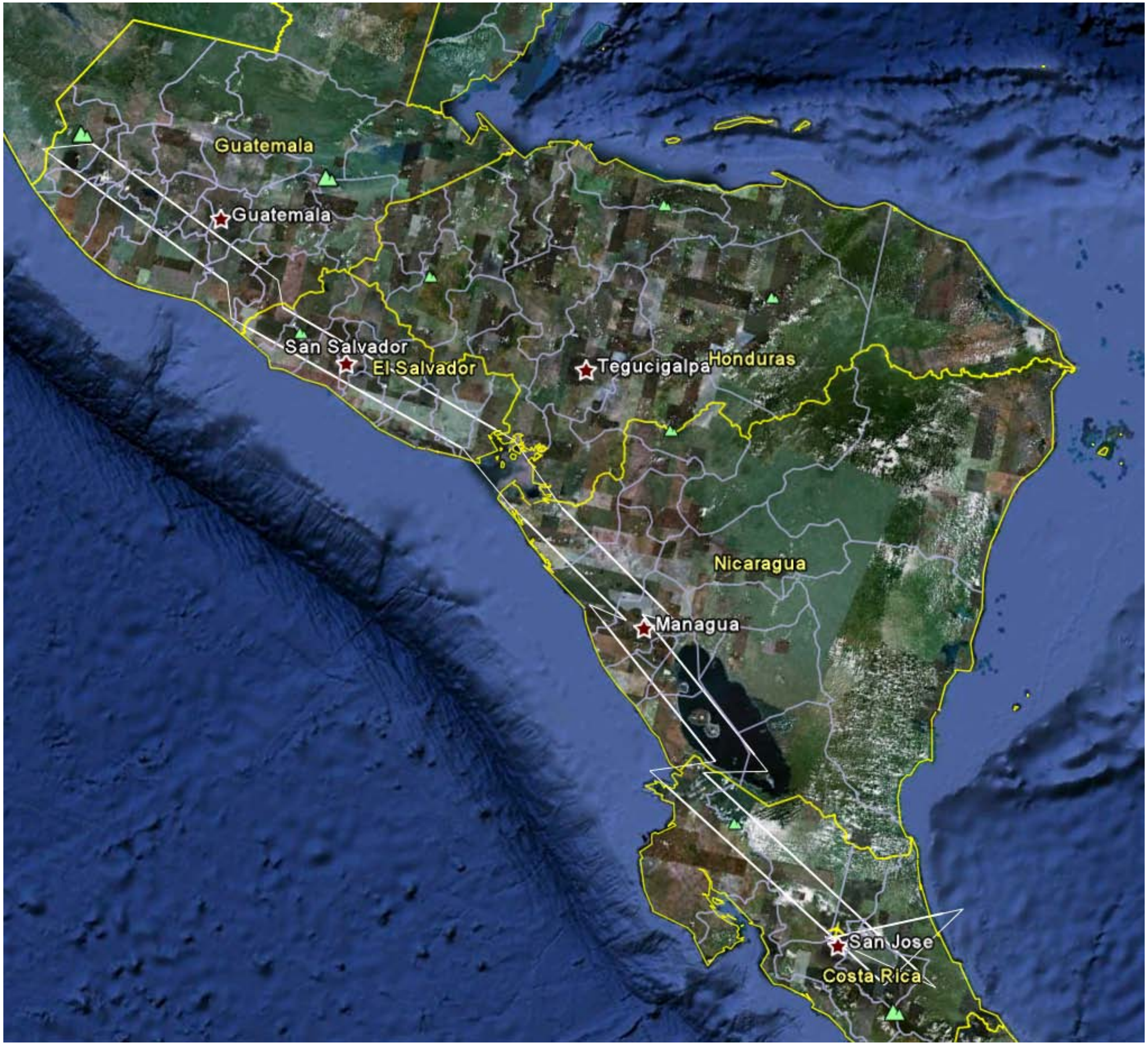
Alaskan Volcano

U.S. Cascades

Paos Volcano, Costa Rica

Central America
- Guatemala
- El Salvador
- Nicaragua
- Costa Rica

Central American Volcanoes



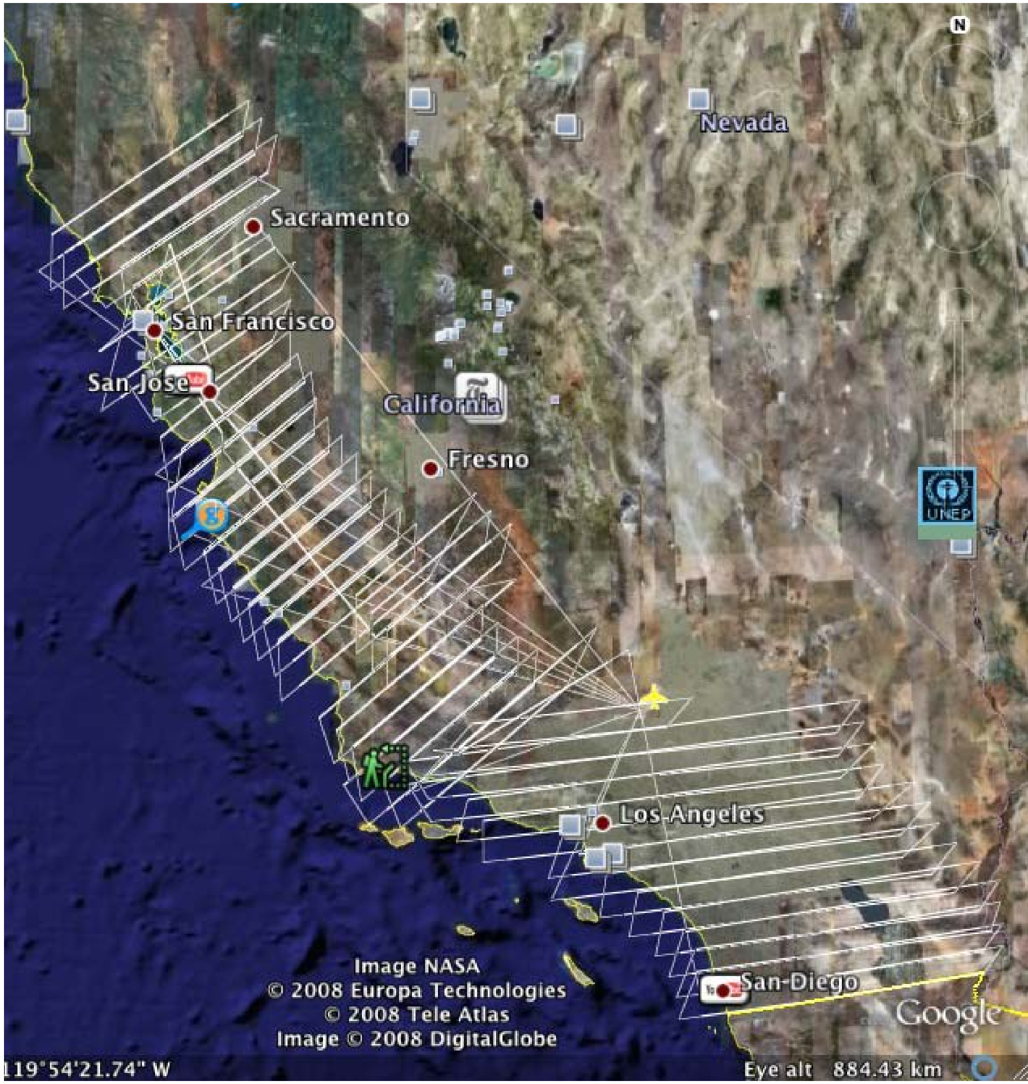
"Lawn Mowing" - San Andreas & Hayward Faults

- Repeat-Pass

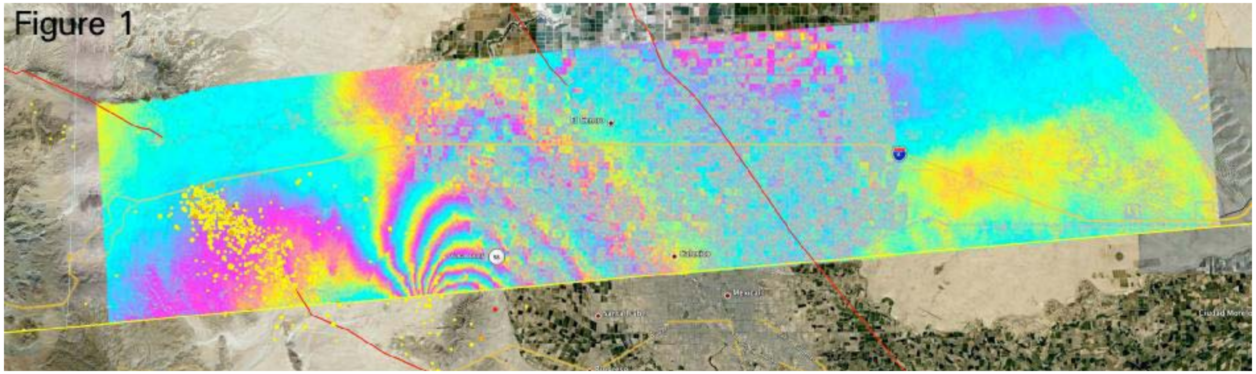
- Every 6 months …
  or after "an event"

  - Deformations measured after Mexicali Easter Earthquake Apr 4, 2010

- 5mm resolution over 3m x 3m area



UAVSAR Analysis of Mexicali Easter Earthquake 2010



80 cm max deformation measured

Kenneth Hudnut, a geophysicist with the U.S. Geological Survey, said the imagery gave scientists a number of revelations. Among them:

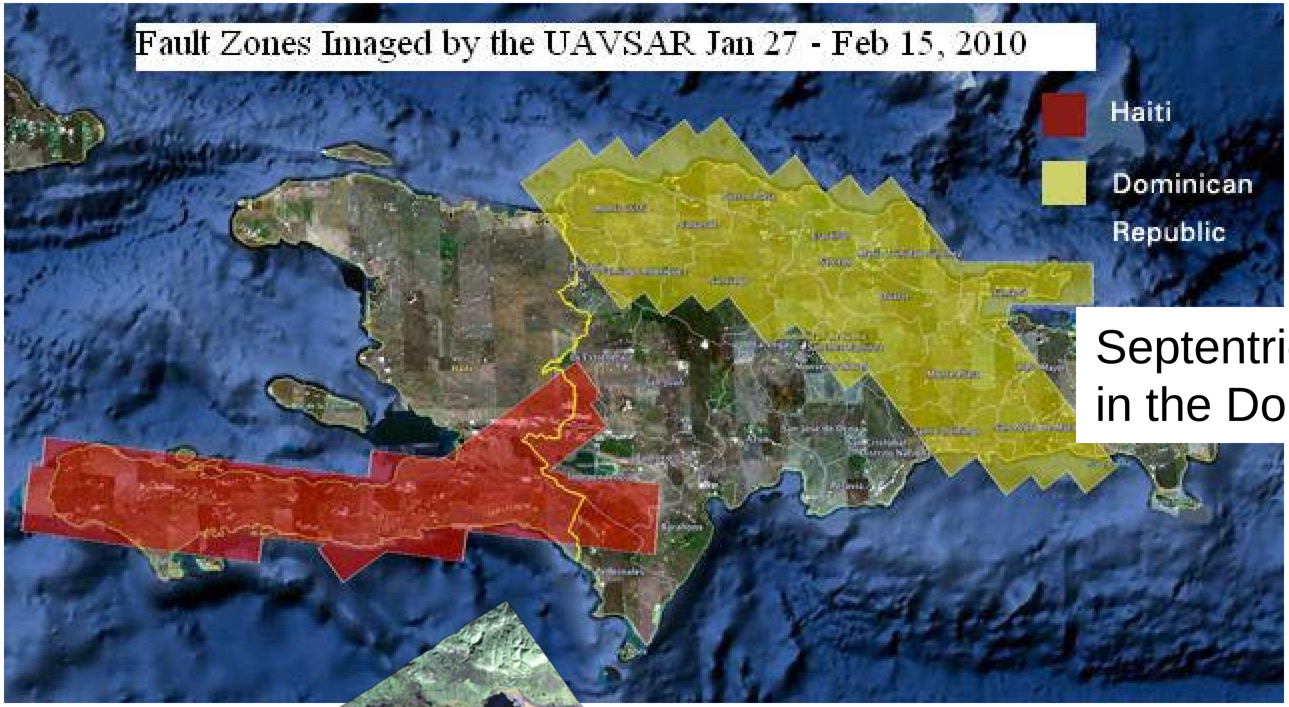
- **Proof** that earthquakes zipping along a fault can jump over gaps as long as 7 miles. Previously, only jumps of 3 miles had been observed.

- **Proof** that earthquake faults are punctuated by sections of high and low tectonic stress, a mix that is responsible for the destructive shaking energy that can collapse buildings.

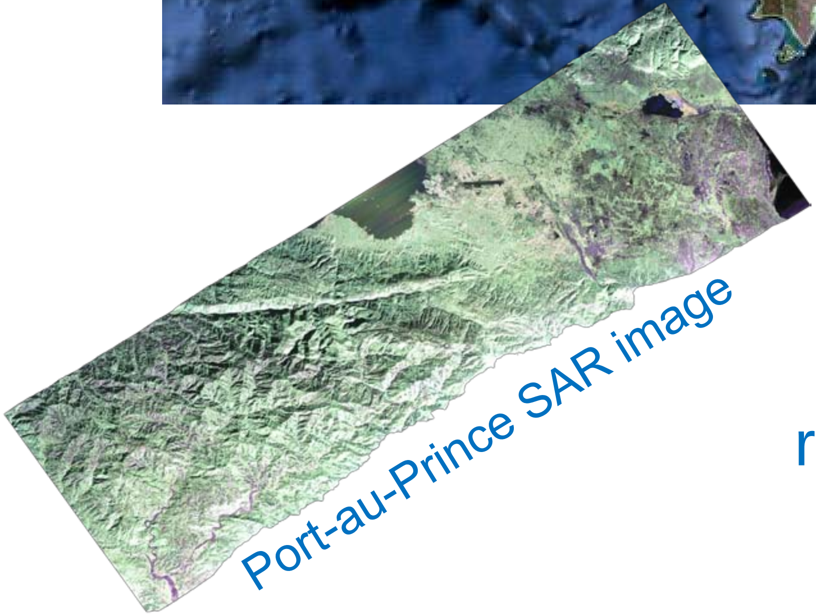
- **Proof** that earthquakes can reverse directions, an observation that had never been seen before.

Hudnut said the April 4 earthquake showed that at one point, the quake was moving northwest, and then somehow swung backward, in what is called a "back rupture.“ … "**That's going to change, in a significant way, the way we do forecast modeling**”

Haiti & Dominican Republic



Septentrional fault mostly in the Dominican Republic



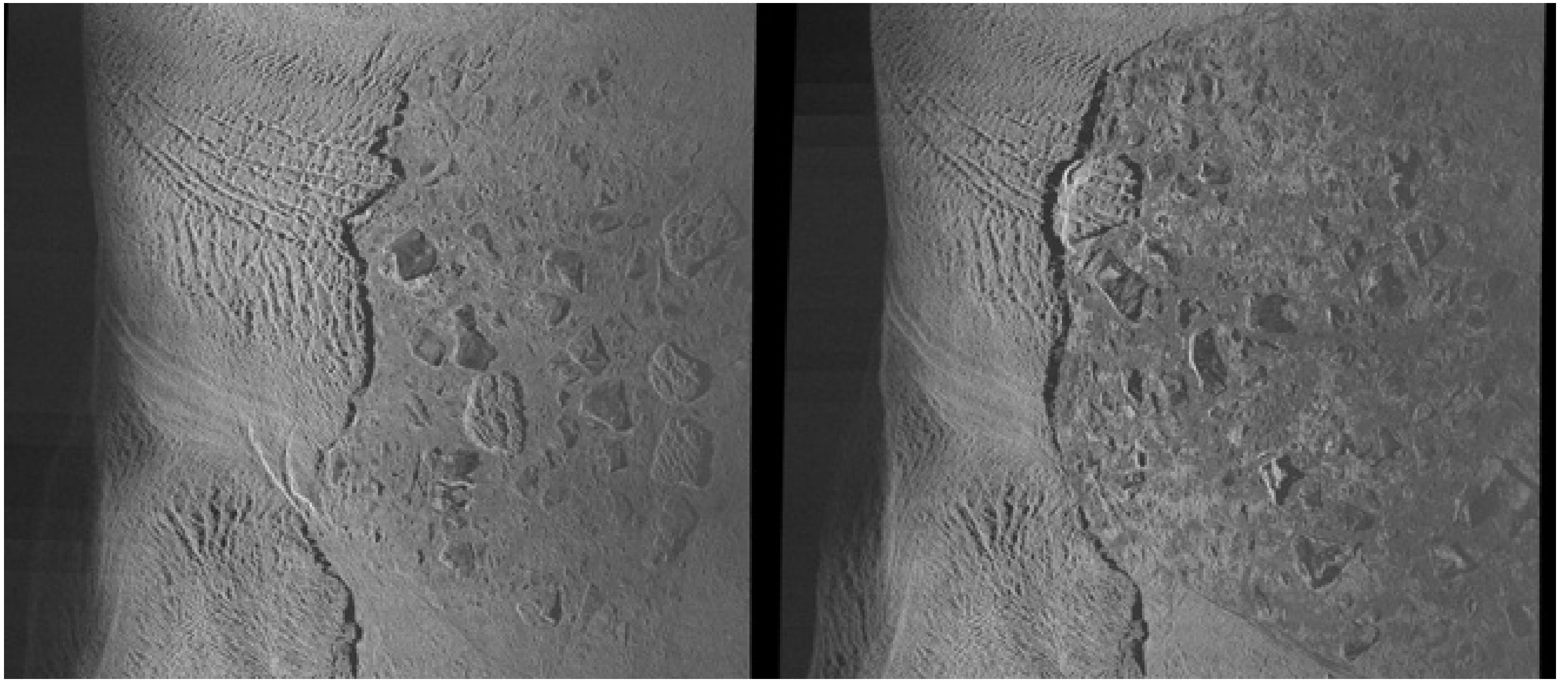
Port-au-Prince SAR image

Enriquillo-Plantain Garden fault ruptured in Haiti on Jan 12, 2010

Ice Dynamics

Greenland Deployment 2009

Jacobshaven Glacier Calving



Two Ka-band images acquired on May 6 (left) and May 12 (right) of Greenland’s Jacobshaven glacier show evidence of ice calving of almost a kilometer during the six-day period

Levee Evaluation

<u>Sacramento Delta Levees</u>

Monthly Imaging

Terrestrial Ecology

<u>Vegetation Structure</u>

- Biomass quantification
- Carbon sequestration
- Climate change
- Calibrated with ground measurements
- Supports Deformation, Ecosystem Structure and Dynamics of Ice (DESDynI) Satellite algorithm development. DESDynI planned launch in 20??

Forests

Mangrove Fields

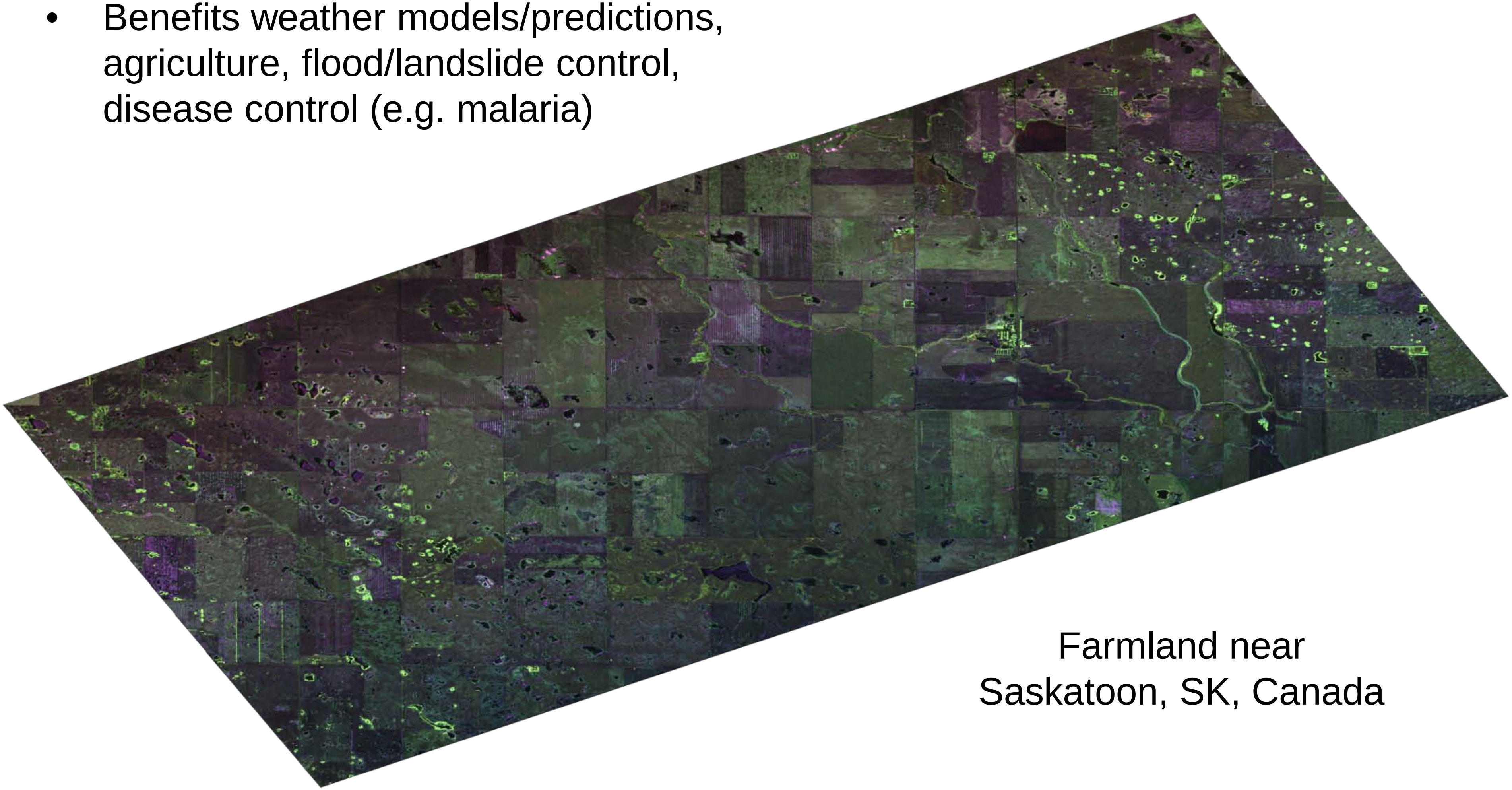
Wetlands

Everglades

Rain Forest
La Selva, Costa Rica

Soil Moisture

- Radar penetrates ~50mm into ground
- Calibrated with ground measurements
- Supports Soil Moisture Active Passive (SMAP) Satellite algorithm development. SMAP planned launch in 2014
- Benefits weather models/predictions, agriculture, flood/landslide control, disease control (e.g. malaria)



Farmland near
Saskatoon, SK, Canada

Oil Spill Response & Recovery

2010 Deepwater Horizon
Gulf Coast Oil Spill

1st ever application of SAR to Oil Spill

<u>Objectives</u>

- Develop and validate algorithms to discriminate oil slicks over water and determine their properties
- Develop algorithms for determining the extent of oil penetration into sensitive coastal ecological zones
- Provide baseline data for long-term analysis of persistence, location and damage recovery processes in various coastal ecological zones

UAVSAR will obtain repeat-pass images of coastal ecosystems in June 2011 to measure oil spill impact

The Future of UAVSAR

P-band antenna under development

- Funded by AirMOSS project
  (Airborne Microwave Observatory of Subcanopy and Subsurface)
- Soil Moisture
- Flight Test begin March 2012
- 350 hours/year in FY12, FY13, and FY14 (including annual visit to Costa Rica)

Ka-band antenna under development

- Funded by GLISTIN-A project under the
  NASA Airborne Innovative Technology Transition Program
  (Glacier and Land Ice Surface Topography Interferometer – Airborne)
- Single-Pass Elevation Mapping
- Flight Test begin Dec 2011
- Initial science targets are Greenland and Alaska … ultimately Antarctica on Global Hawk

Global Hawk Integration

- Funded by the NASA Earth Science Technology Office (ESTO)
- Requires two smaller-diameter pods
- L & Ka band antennas (possibly P-band)
- Single-pass interferometry

Questions?

http://www.nasa.gov/centers/dryden/aircraft/G-III_UAVSAR

http://uavsar.jpl.nasa.gov